OUTLOOK ON ECOLOGICAL IMPROVED COMPOSITES FOR AVIATION INTERIOR AND SECONDARY STRUCTURES

Introduction of the new EU-China project **ECO-COMPASS** within Horizon 2020

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Greener Aviation 2016

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Content

- Background
- Introduction to the ECO-COMPASS project
- Applications for eco-composites in aviation
- Status and outlook on selected ecological improved materials

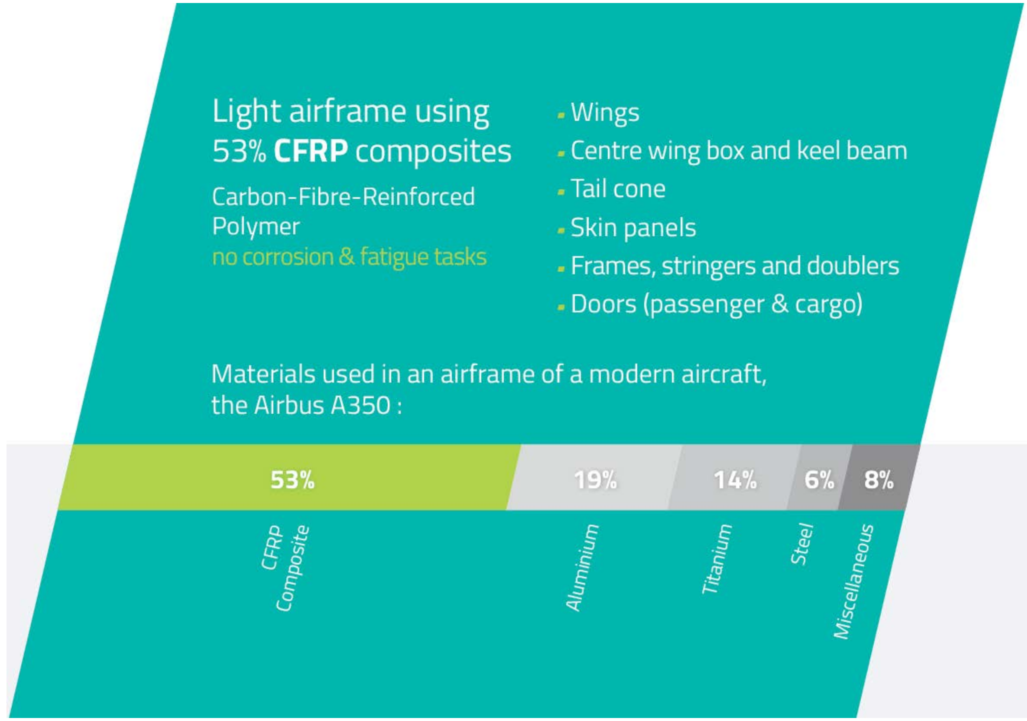
Background

- Composites used in aviation today:
  - CFRP (fuselage, wings, etc.)
  - GFRP (interior, secondary structures)

→"Eco"-materials?

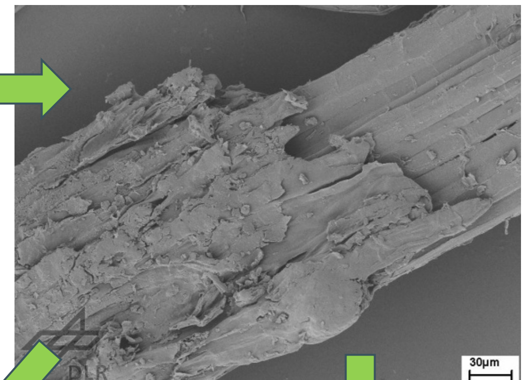
- Bio-based resins and fibres
- Expected benefits:
  - \+ Reduced environmental footprint
  - \+ Conservation of resources
  - \+ Weight reduction

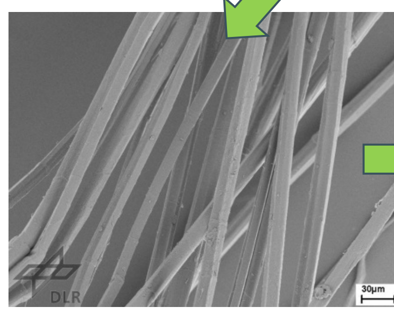
- Recycled carbon fibres (rCF)



Background

Flax (Linum usitatissimum)





Ramie (Boehmeria nivea)

[Wang et al 2015]

Background

Fibre properties
based on [Dicker et al. / Composites: Part A 56 (2014) 280-289]

Fibre type		*Density*	*Price*	*Young's modulus*	*Tensile Strength*	*Elongation*	*Length*	*Diameter*	*Moisture content*	*Cellulose*
		[g/cm³]	*[USD/kg]*	*[GPa]*	*[MPa]*	*[%]*	*[mm]*	*[µm]*	*[wt-%]*	*[wt-%]*
Synthetic	Carbon HS	1.8-1.84	124-166	225-260	4400-4800	1.5	-	5-10	-	-
	E-glass	2.55-2.6	1.63-3.26	72-85	1900-2050	1.8-4.5	-	<10	-	-
Fruit	Coir	1.15-1.22	0.25-0.5	4-6	135-240	15-35	20-150	10-460	8	32-43.8
	Cotton	1.52-1.56	2.1-4.2	7-12	350-800	5-12	10-60	10-45	7.85-8.5	82.7-90
Bast	Flax	1.42-1.52	2.1-4.2	75-90	750-940	1.2-1.8	5-900	12-600	8-12	62-72
	Hemp	1.47-1.52	1-2.1	55-70	550-920	1.4-1.7	5-55	25-500	6.2-12	68-74.4
	Jute	1.44-1.52	0.35-1.5	35-60	400-860	1.7-2.0	1.5-120	20-200	12.5-13.7	59-71.5
	Ramie	1.45-1.55	1.5-2.5	38-44	500-680	2.0-2.2	900-1200	20-80	7.5-17	68.6-85
Leaf	Sisal	1.4- 1.45	0.6-0.7	10-25	550-790	4.0-6.0	900	8-200	10-22	60-78
Grass	Bamboo	0.6-1.1	0.5	11-32	140-800	2.5-3.7	1.5-4	25-40	-	26-65

Background

Challenges

- Fulfillment of demanding requirements in aviation
  - Mechanical properties
  - Fire properties
    - Heat Release
    - Flammability
    - Smoke Density & Toxicity
    - Flame penetration resistance (Cargo)
- Variable fibre properties
- Durability (Resistance to climate, UV, cleaning agents)
- Modifications and their effects on environmental impacts

ECO-COMPASS

Ecological and Multifunctional Composites for Application in Aircraft Interior and Secondary Structures

- Cooperation of Chinese and European partners
- 04/2016 – 03/2019

- Identification of applications for eco- and multifunctional composites
- Development, characterization and simulation of eco-materials to give a broad overview of the possibilities in aviation with leverage to other transport sectors like automotive and railway.
- Application / Demonstrators
- Life Cycle Assessment (LCA)

Consortium

8 EUROPEAN PARTNERS FROM 6 COUNTRIES

11 CHINESE PARTNERS

AIRBUS GROUP INNOVATIONS

CENTRE INTERNACIONAL DE METODES NUMERICS EN ENGINYERIA

DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV

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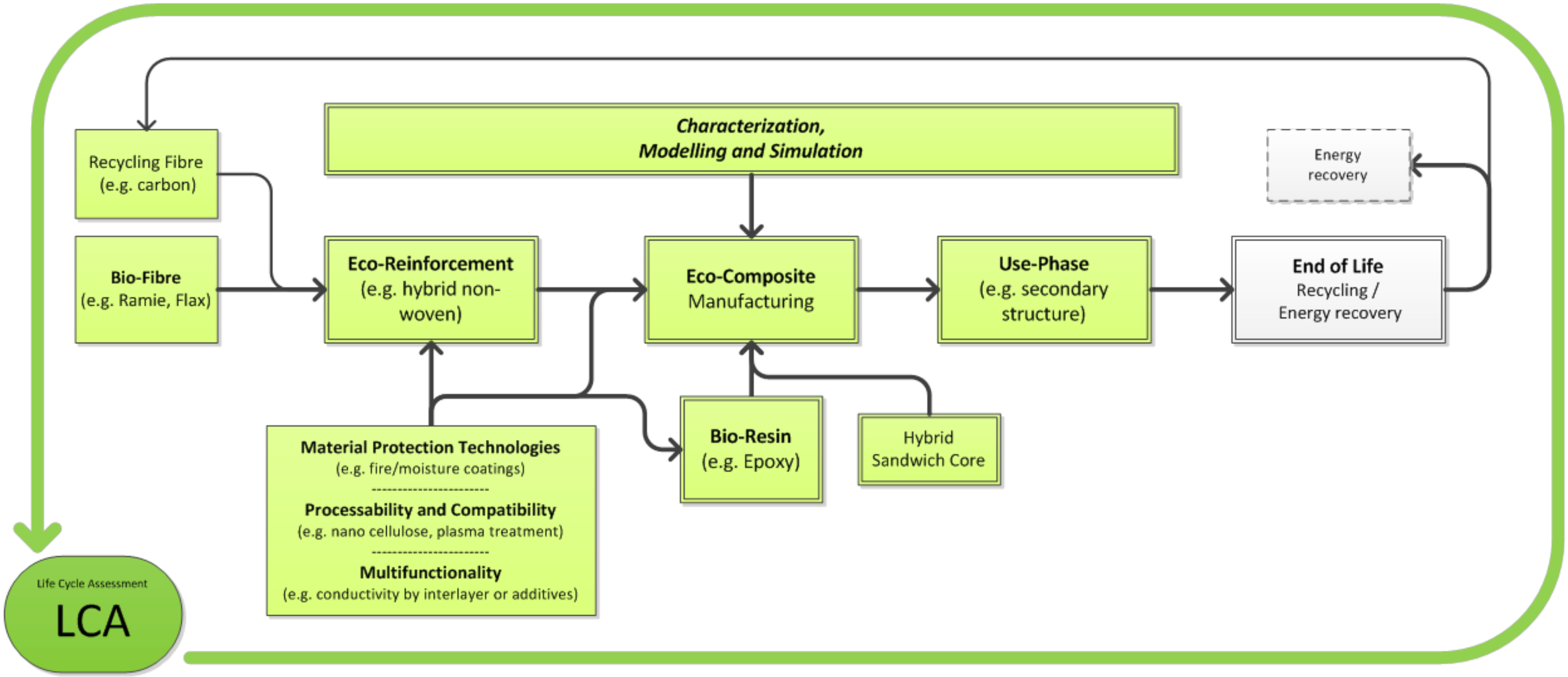
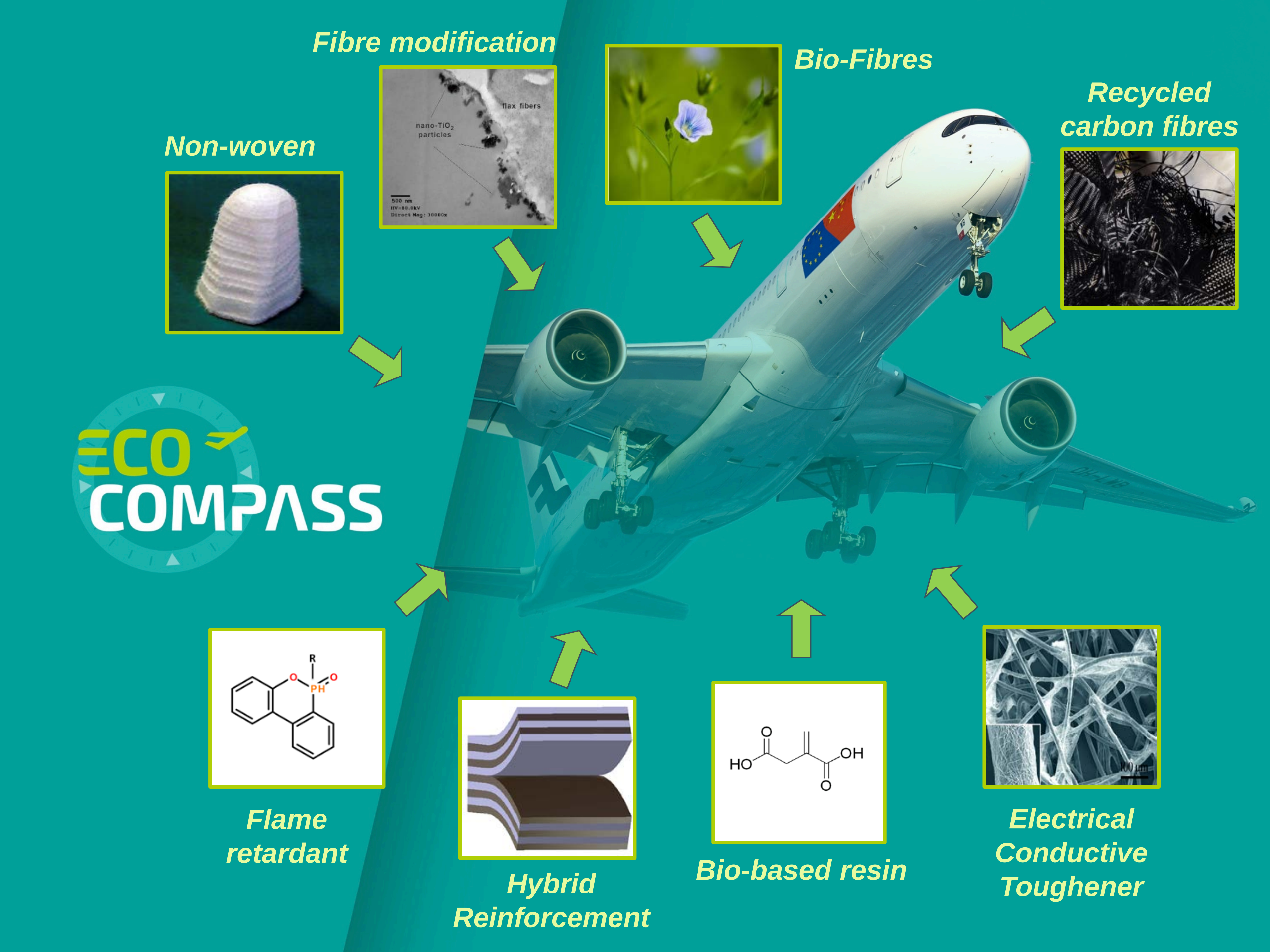
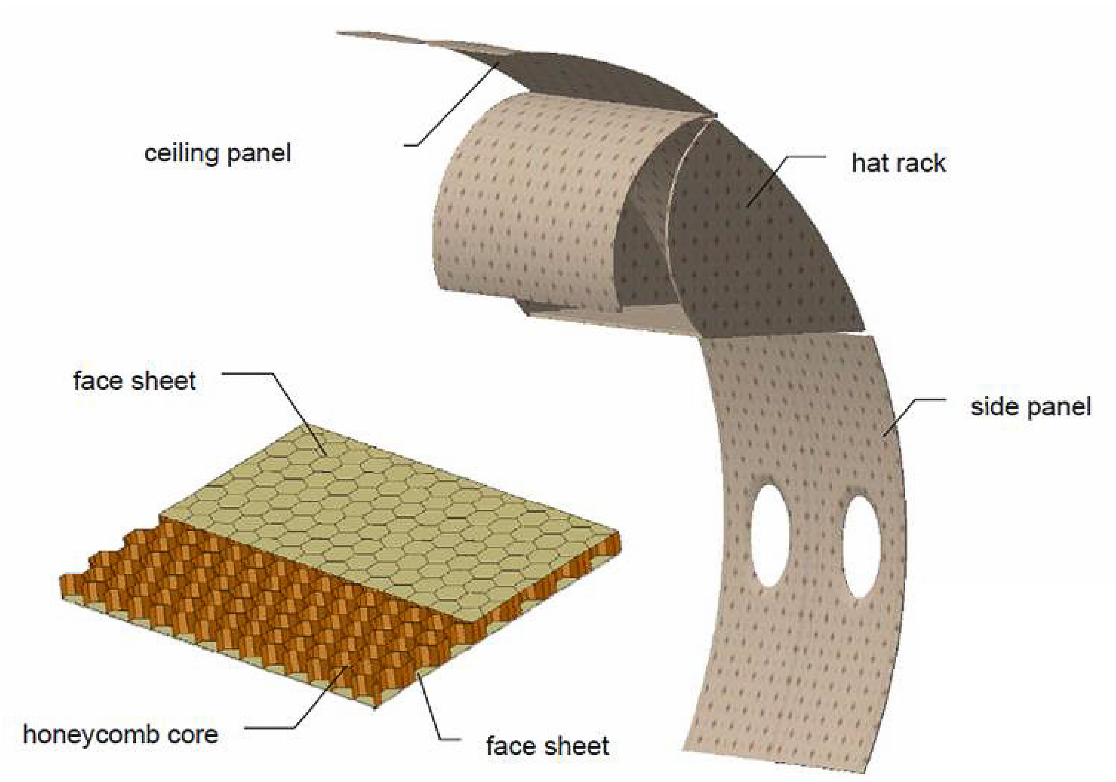
Approach

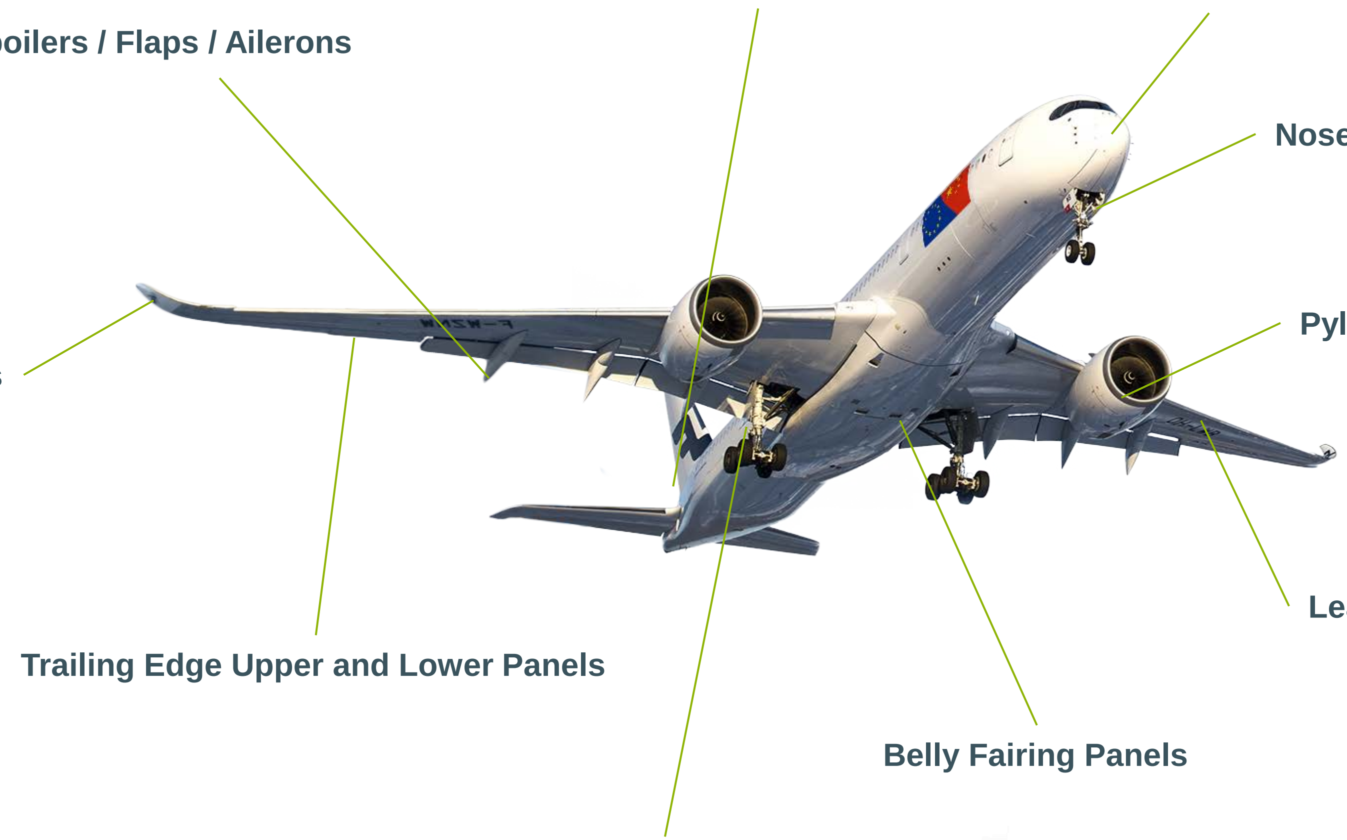

Recycling Fibre (e.g. carbon)
Characterization, Modelling and Simulation
Energy recovery
Bio-Fibre (e.g. Ramie, Flax)
Eco-Reinforcement (e.g. hybrid non-woven)
Eco-Composite Manufacturing
Use-Phase (e.g. secondary structure)
End of Life Recycling / Energy recovery
Bio-Resin (e.g. Epoxy)
Hybrid Sandwich Core
Material Protection Technologies (e.g. fire/moisture coatings)
Processability and Compatibility (e.g. nano cellulose, plasma treatment)
Multifunctionality (e.g. conductivity by interlayer or additives)
Life Cycle Assessment
LCA


Fibre modification
flax fibers
nano-TiO2 particles
500 nm
Bio-Fibres
Recycled carbon fibres
Non-woven
ECO COMPASS
Flame retardant
Hybrid Reinforcement
Bio-based resin
Electrical Conductive Toughener

Potential Application: Interior



Potential Application: Secondary Structures



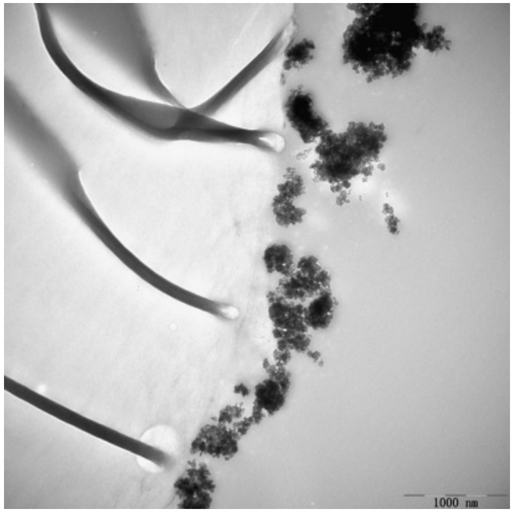
Modification of Bio-Fibres

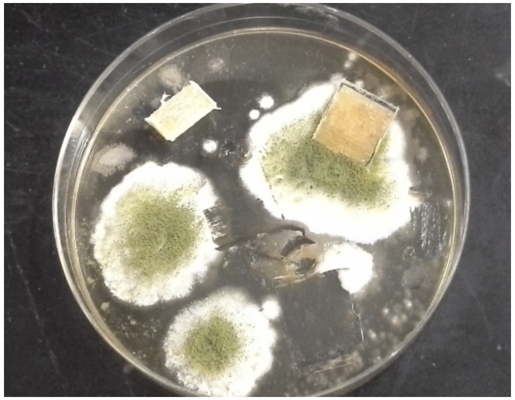
Grafting

- Nano-particles (ZrO2)
- Grafted through hydrogen bonds to flax fibre
- Improvement of tensile strength
- Antimicrobial

Other examples for fibre modification:

- Nano-natural cellulose
- Plasma treatment
- Alkali treatment

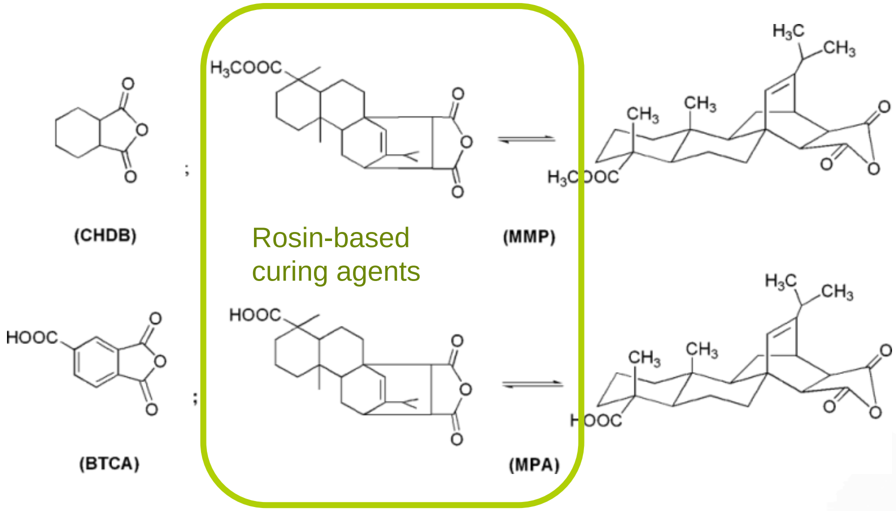




[Wang, H., Xian, G. and Li, H. (2015). Composites Part A: Applied Science and Manufacturing]

Bio-Resins

- Focus on thermosets in ECO-COMPASS
- Renewable base-materials:
  - Linseed oil, soybean oil, starch, agricultural waste, etc.
- Furanic resin based on prepolymers of furfurylic alcohol already available (sugarcane bagasse) in Europe and China
- **Epoxy resin (based on rosin, itaconic-acid or gallic acid)**

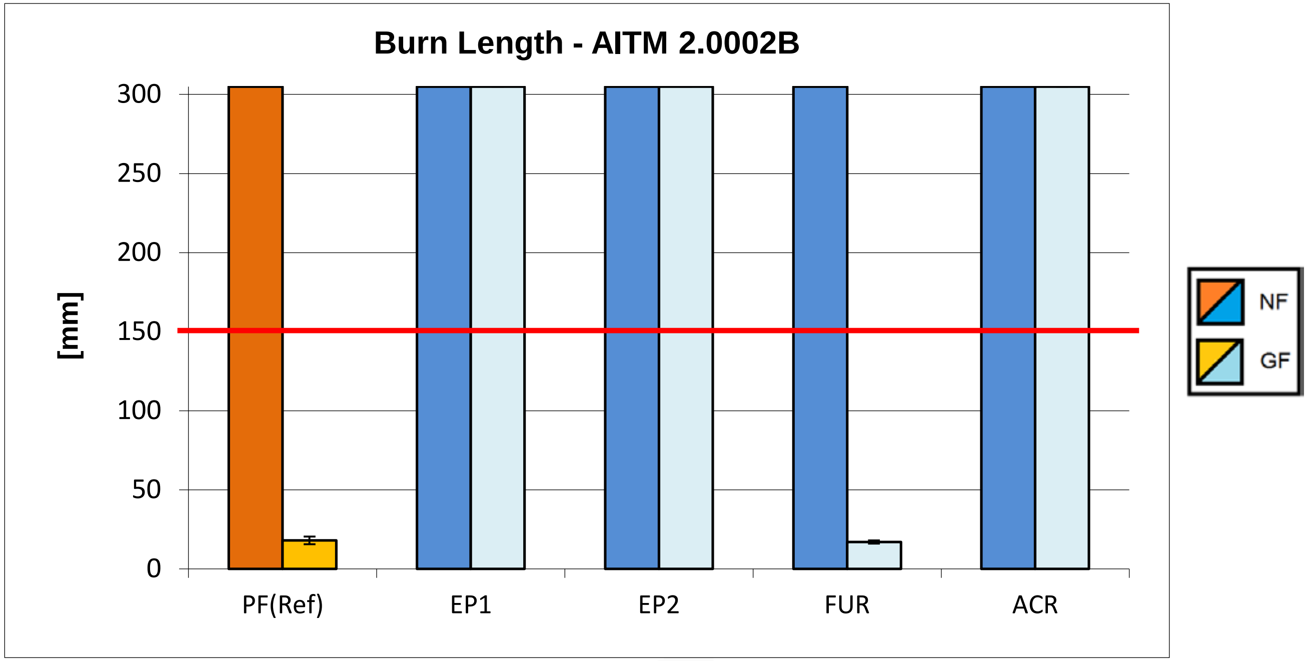


[Li, C. et al (2013). Journal of Macromolecular Science, Part A: Pure and Applied Chemistry, Vol. 50]

Fire Properties

- Comparison of bio*-resins with standard phenolic
- No flame retardants for bio-resins
- Natural fibre (NF) and glass fibre (GF) reinforcement

PF = Phenolic
EP = Epoxy
FUR = Furan
ACR = Linseed Acrylate

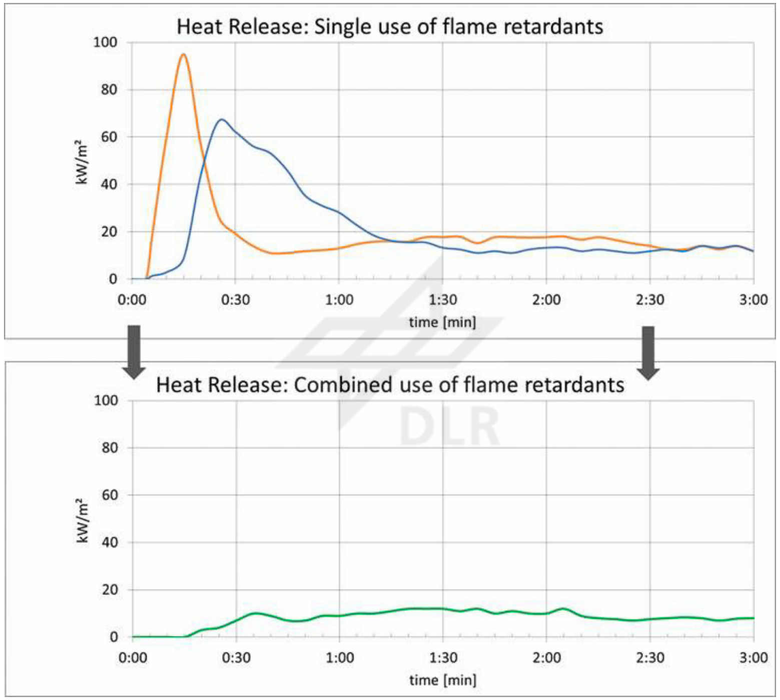


[Bachmann, J., Fischer, H. – Bioharze und flammgeschützte Naturfasern: Nachhaltige Materialien für das Flugzeuginterieur? – AVK-Flammschutz bei Composites-Anwendungen, Frankfurt, 10.12.2013]

*) Resin at least partially bio-based

Fire Properties

- Fire properties of natural fibre reinforced plastics (Interior, Sandwich)
- Fibre: Flax (plain weave, 185 g/m²)
- Resin: Phenolic



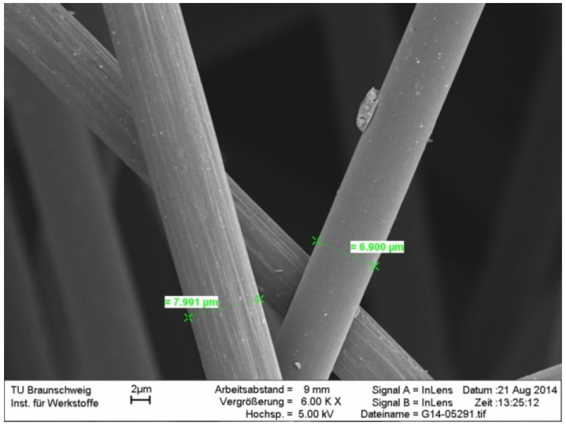
[Bachmann, J., Michelis, B. – Verbesserung der Brandeigentschaften von NFK im Hinblick auf den Luftfahrt-Kabineneinsatz – Köln 2011]

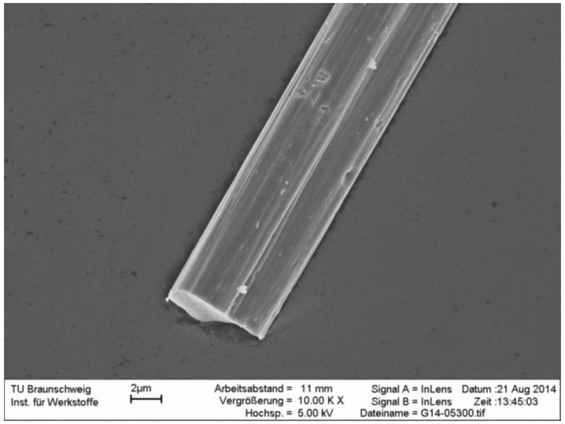
ECO COMPASS

Recycled Carbon Fibres

- Pyrolysis process industrially available
- Elimination of fibre sizing
- Restricted fibre length
- Resin residue and/or „craters“ on rCF, but fibre tests show:
- Strength of rCF comparable to vCF when pyrolysis process is under control
- First tests on hybrid non-woven show increased flexural strength and stiffness compared to pure NF composite

[DLR]





vCF = Virgin Carbon Fibre
rCF = Recycled Carbon Fibre

Conclusions

- Interior and Secondary Structures are possible application scenarios for eco-composites, e.g. fairings and linings.
- Bio-fibres (e.g. flax, ramie) offer promising specific properties. Modifications of fibres to enhance their properties will be investigated.
- Bio-resins could substitute petrol-based resins
  - Furan resins show similar fire properties compared to phenolics
  - Itaconic-acid, gallic-acid and rosin based bio-epoxy resin from China
- Hybrid composites based on bio-fibres and recycled carbon fibres could increase the mechanical properties and application range of eco-composites
- Demanding safety requirements (e.g. FST) have to be fulfilled without adverse effects on mechanical properties and weight

→ Life Cycle Assessment (LCA) to calculate the environmental impact from cradle to grave is important to compare „eco-composites“ with state of the art materials

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